Density Zone	Weighted Average Dispersion
< 5	4.48
5 – 100	1.28
101 – 200	0.55

INDETEC's focus was on the low-density CBG's in US West's Colorado service territory. These CBG's are characterized by less than 5 households per square mile. The focus here is on the least dense areas because it is in these areas that errors in assumptions concerning the degree of clustering can have a substantial effect on estimated cable lengths. As shown in Table 4, there are 186 CBG's in US West's Colorado service territory that fall in this density classification. Although these CBG's account for 6 % of the total number of populated CBG's in US West's service territory, they account for 81 % of the service territory land area.[17]

Table 4. US West Colorado CBG's by Household Density.

Households per SQMI	Number of CBG's	Area (SQMI)	CBG Area as % of USW Territory
0	30	45	< 1
< 5	186	37,150	81
5 – 100	347	7,207	16
101 – 200	122	369	1
201 – 650	314	376	1
651 – 850	127	81	< 1
851 – 2,550	1,124	326	1
2,551 – 5,000	675	107	< 1
5,001 – 10,000	84	8	< 1
> 10,000	60	3	< 1

Note: Based on BCPM Colorado database adjusted for US West wire center boundaries.

Statistics for three of these 186 low-density CBG's are shown in Table 5 with actual housing unit locations shown in maps attached to this paper. These CBG's are: 81159984001, located in Sedwick County in northeastern Colorado; 80159606003, located in Chaffee County in central Colorado; and, 80719834002, located in Las Animas County in south central Colorado. These CBG's were chosen to represent the different terrain types of Colorado rural areas, primarily plains and mountains. The attached maps show the housing units that can be clearly identified (and geo-coded) from satellite photographs of these CBG's. For the three CBG's 81159984001, 80159606003, and 80719834002, 88%, 25%, and 69 % of the US Census housing

[17] For the entire State of Colorado, CBG's with fewer than 5 households per square mile comprise 90% of the State's land area. This is consistent with other western States. Low-density CBG's in Nevada, for example, comprise 93% of the State's land area. Midwestern states also exhibit this characteristic, but to a lesser extent. Low-density CBG's in Iowa, for example, comprise 60% of the State's land area.

units could be identified in the satellite images.[18] These maps indicate the actual level of dispersion in these CBG's.

The fifth column of Table 5 shows the measure of actual dispersion utilized here for each CBG. Higher values indicate greater dispersion. The dispersion measure for CBG 81159984001 is 5.74 indicating a relatively high level of actual housing unit dispersion. This is consistent with the map for this CBG, which shows that housing units are indeed uniformly distributed. Housing units in CBG 80159606003 are slightly more clustered than in 81159984001. The map for 80159606003 indicates that housing units are located in the upper half of the CBG, likely the result of mountains in the southern portion of the CBG. However, within the occupied portion of this CBG, the measure of actual dispersion (5.17) suggests a relatively low degree of clustering. CBG 80719834002 exhibits substantially more clustering than the previous two CBG's. This is consistent with the map of this CBG, which illustrates clustering. Clearly the length of cable used per subscriber is greater in the first two CBG's in Table 2 than in the third. In estimating the length of cable runs one must consider the *dispersion* of housing units as well as the *density* of those units.

Table 5. Three US West Colorado CBG's.

CBG	Households	Households per SQMI	% CBG Occupied	CBG Dispersion	Dispersion Actual Quad/Hatfield Quad
81159984001	94	0.57	62.3	5.74	6.50
80159606003	180	1.58	93.6	5.17	2.62
80719834002	424	3.60	86.7	3.20	2.08

Colorado Dispersion Findings: Hatfield vs. Reality

The last column of Table 5 shows the dispersion implied by the Hatfield 4.0 algorithm relative to a measure of dispersion that more accurately reflects the actual dispersion of housing units in a CBG. For CBG 81159984001, the ratio of the "realistic" to Hatfield dispersion is 6.5.[19] In other words, the actual level of housing unit dispersion in this CBG is, on average, 6.5 times that assumed by the Hatfield 4.0 Model. The Hatfield 4.0 Model *understates* the degree of dispersion in CBG

[18] The relatively small proportion of housing units that could be observed in CBG 80159606003 is the result of there being a large number of mobile homes in this CBG. Mobile homes are difficult to discern from the satellite images at the level of resolution used for this analysis.

[19] The term "realistic" is in quotes to stress that the measure is based on actual CB data.

80159606003 to a lesser extent. That is, the actual level of housing unit dispersion in this CBG is, on average, 2.6 times that assumed by the Hatfield 4.0 Model. A similar level of understate by the Hatfield Model is made for CBG 80719834002.[20]

In fact, the majority of low-density CBG's (fewer than 5 households per square mile) in US West's Colorado service territory exhibit the same characteristic as that shown in the last column of Table 2. For 91% of these low-density CBG's, the calculated Hatfield Model dispersion measure is *lower* than INDETEC's more realistic measure. CBG's for which the Hatfield Model underestimates dispersion comprise 98 % of the area of low-density CBG's in US West's Colorado service territory. In other words, for 98 % of the area of US West's low-density CBG's, the Hatfield 4.0 Model *exaggerates* the clustering and underestimates the dispersion. Moreover, this underestimation is not inconsequential. On average, for the 91% of the CBG's whose dispersion is underestimated by the Hatfield 4.0 Model, the realistic dispersion is 3.1 times that implied by the Hatfield 4.0 Model.

In the remaining 9 % of the low-density CBG's, the Hatfield 4.0 Model does not underestimate dispersion. In fact, the Model sometimes overestimates dispersion. However, even when these *overestimated* CBG's are included in the mix, for the *entire* population of low-density CBG's in US West's Colorado service territory, the realistic dispersion is still 2.9 times that implied by the Hatfield 4.0 Model.

[20] The Statewide town factor of 84% for the low-density CBG's (ratio of non-farm rural 1990 population to 1990 rural population) was used to generate the Hatfield 4.0 CBG dispersion measures.

III. The Hatfield Model Clustering Algorithm

The "Town Factor"

The ties between the Hatfield Model's clustering algorithm and actual customer locations are tenuous at best. The Model essentially employs only 2 reality-based data elements in its clustering algorithm: (1) the percent of CBG area that is occupied; and, (2) a Town Factor, defined as the ratio of non-farm rural population to rural population in the CBG.[21] The Model does not employ any actual data on customer locations. The rest of the clustering algorithm is based on assumptions for which no empirical evidence is given.

The Model divides a CBG into four quadrants. If the occupied area share of the total CBG area is greater than 50%, then customers are located in two, diagonally-opposed quadrants. Otherwise, customers are located in all four quadrants. For all CBG's in the three lowest density zones and CBG's in the other zones having more than 50% empty area, a Town Factor is used to apportion the CBG housing units between "towns" and "out-of-town" areas. A "Town Lot Size" user-defined input determines the size of the lots within the "towns." The default value is 3 acres.

Hatfield 4.0 allows the user to specify a Town Factor for each CBG. Table 6 shows the average Town Factor (weighted by CBG housing units) for the least dense areas in the State of Colorado. Derivation of the CBG Town Factor is based on 1990 Census data.[22] Again, the Town Factor indicates that in the least dense areas of Colorado (less than 5 households per square mile), on average, 87% of the housing units in a CBG are forced into a "cluster" or "town" by the Model's clustering algorithm.[23]

The developers of the Hatfield Model have presented no empirical evidence that there is a high correlation between the Town Factor and actual clustering of customers. However, the dispersion measure developed here allows for a test of the reasonableness of the Hatfield Town Factor as a measure of customer clustering. Table 6 also shows for the Colorado CBG's with fewer than 200 households per square mile the 1990 Census "Town Factor" and the simple correlation between this Town Factor and the "realistic" measure of CBG housing unit dispersion.

---

[21] Hatfield Model Release 4.0 Inputs Portfolio.

[22] The Hatfield Model Release 4.0 Inputs Portfolio indicates values for a state level Town Factor taken from the 1995 Statistical Abstract. The values used reflect 1990 data. The most recent *CBG level* data available for use are for 1990 and are taken from the Census' Summary Tape Files.

[23] This analysis uses a Town Factor calculated for each CBG. Aggregation to the density zone level yields a slightly different value than if aggregate population data were employed. For example, aggregate data yields a Town Factor of 84% for the low-density zone while using CBG level data yields a weighted-average Town Factor of 87%.

Table 6. Colorado CBG's: Correlation between Housing Unit Dispersion and the Hatfield Model "Town Factor"

Households per Square Mile	Average Town Factor*	Correlation Between Town Factor and CBG HU Dispersion
Less than 5	0.87	-0.377
5 to 100	0.96	-0.216
101 to 200	0.97	0.002

*Housing unit weighted average

As Table 6 shows, in the least dense CBG's, the correlation between the Hatfield Town Factor and the measure of housing unit dispersion is negative. This is what one would expect if the Town Factor is a proxy for customer clustering. However, the correlation is quite low. Moreover, the correlation between the Town Factor and the dispersion measure declines as CBG density rises. One would expect a negative and very high correlation in the denser CBG's, CBG's that are, in reality, characterized by more housing unit clustering.[24]

The inadequacy of the Town Factor as a proxy for customer clustering can be seen in the CBG maps attached to this paper. The Hatfield Town Factor for these CBG's is shown in Table 7. A comparison of these Town Factors with the housing unit dispersion depicted in the maps exemplifies the low correlation shown in Table 6. The map for CBG 81159984001 clearly shows that housing units are more or less uniformly distributed. Yet, the Hatfield Town Factor for this CBG is 81% indicating to the Model that 81 % of the housing units should be clustered in towns. The Town Factor is a very poor proxy for customer clustering.

Table 7. Town Factors for Mapped CBG's.

Map CBG's	Hatfield Town Factor
81159984001	81 %
80159606003	100 %
80719834002	100 %

Demonstration of the Hatfield Error

As demonstrated above, the level of housing unit dispersion assumed by the Hatfield 4.0 Model (in the less than 5 lines per square mile density zone) is substantially lower than the "actual" level of dispersion in Colorado. The reason for this is that the

[24] The Town Factor for the low-density zone for the US West service territory is 91% versus the Statewide value of 87%.

Model's clustering algorithm forces the "Town Population" to reside in a very small portion of the CBG's occupied area.

A very crude way to inject more realism into the Model is to adjust the Town Lot Size. The Town Lot Size is meant to size the lots of those customers living in "towns" or "sub-clusters." If, in reality, there is no clustering (i.e., housing units are more or less uniformly distributed), then one can attempt to crudely approximate this by increasing the Town Lot Size substantially. For example, suppose that there is no clustering in the least dense CBG's. Then, the "effective lot size" would be the number of housing units divided by the occupied CBG area since the Model assumes contiguous lots within the clusters. Depending upon the size of the CBG and its population, this effective lot size could be quite large (e.g., 100 acres). The intent of this exercise is not to suggest that actual Colorado rural lots are 100 acres. Rather, the intent of the exercise is make the best adjustment to the Model that is possible in order to take into account the actual dispersion of housing units in the least dense CBG's.

The problem with this methodology, and the reason why it should be considered for demonstration purposes only, is that the Model does not allow the user to specify a Town Lot Size for each density category or CBG. Rather, the Town Lot Size applies to all three of the low-density zones. Moreover, as shown in Table 6, the average level of dispersion in Colorado's CBG's declines as density increases. That is, CBG's in the 100 to 200 line per square mile density group tend to exhibit, on average, less housing unit dispersion than those in the least dense group. Hence, what is needed is an "average" Town Lot Size, one that can be applied across all three low-density zones.

First, examining the maps of 3 typical Colorado CBG's in the least dense zone (less than 5 lines per square mile) with the geo-coded locations of housing units, visible from satellite photographs (attached), shows very little clustering. How might the Hatfield clustering algorithm be modified to more accurately reflect the actual dispersion (i.e., limited clustering) in these CBG's? In other words, what would have to be the size of the clusters if the Model algorithm was applied to actual housing unit locations? Since there is very little clustering in these typical CBG's, the "clusters" are quite large. In fact, on average, 46% of the occupied CBG area was included in these arbitrary clusters. In other words, 84% of the CBG housing units reside in 46% of the occupied CBG area. Applying this 46% factor to all CBG's in the least dense zone and assuming, as does the Model, contiguous lots within a cluster, yields an effective average lot size of 366 acres. Restricting the analysis to only the US West service territory yields an effective average lot size of 227 acres.

In contrast, the Hatfield Model would assume that 84% of the housing units reside in clusters on 3-acre lots. There are 27,896 square miles of occupied area and 67,575 housing units in the low-density zone of US West's Colorado service territory. If 84% of these housing units are clustered on 3-acre lots, then the share of occupied land area comprised by these clusters is, on average, only 0.97% (i.e., $(((130{,}680/5{,}280^2)*67{,}575*0.84)/27{,}296)*100$). *In other words, the Hatfield Model would assume that 84% of the housing units are located on less than 1% of the occupied land area.*

The next step is to scale downwards this 46% factor for the 5 to 100 and 100 to 200 density groups. This scaling downward approach is utilized since the calculated "realistic" dispersion measure declines substantially over this range. This was accomplished by comparing each density group's dispersion measure with that of the lowest density group (5 or fewer lines per square mile). A housing unit weighted average effective lot size was then calculated for the three low-density CBG zones. This effective lot size is 108 acres, 52 acres for the US West service territory. Throughout this process a constant Town Factor of 84% was assumed.

It is important to recognize that the methodology described above is crude and should be considered for demonstration purposes only. The Model does not allow for a true "fix" for its inability to accurately account for housing dispersion in rural CBG's. A more reasonable adjustment would require the use of input data that indicates where customers are actually located on a very disaggregated scale. This is the type of data used by BCPM2. The "effective lot size" approach is an attempt to show that costs are very likely to increase when the Hatfield Model is forced, in a crude way, to better account for actual housing unit dispersion in the rural CBG's. It does not appear that 108 (52) acres is the "correct" number for the "effective lot size." Rather this is the only available fix in the context of the current Hatfield Model.

Table 8 shows the effect on the US West Colorado default loop investment and monthly loop cost estimates when an effective lot size of 52 acres is used instead of the 3-acre default. The default investment and cost estimates are derived using the 1990 Census-based, CBG-specific Town Factors for Colorado.

Table 8. Demonstration of the Effect of Using an Effective Lot Size on Hatfield Default Loop Investment and Cost: US West Colorado.

Density Zone	Default Loop Investment ($ per line)	Default Loop Cost per Month ($ per line)	Adjusted Loop Investment ($ per line)	Adjusted Loop Cost per Month ($ per line)
< 5	**5,587**	**105.35**	**6,406**	**119.94**
5 – 100	**1,691**	**36.58**	**1,963**	**41.90**
101 – 200	1,004	22.59	880	20.99
201 – 650	721	16.64	732	16.86
651 – 850	629	13.84	624	13.75
851 – 2,550	588	12.01	587	11.98
2,551 – 5,000	565	10.60	565	10.61
5,001 – 10,000	476	8.64	478	8.69
> 10,000	278	5.62	278	5.64
Average		13.92		14.48

One would expect the largest effect to occur in the lower-density zones, those in which the Hatfield 4.0 Model substantially overstates the degree of customer clustering. This is indeed the case. Using an effective lot size of 52 acres results in a 14.7 and 16.1 % increase in the loop investment per line in the less than 5 and 5 to 100 lines per square mile density zones. The effect on the monthly loop cost is somewhat smaller (13.9 and 14.5 %). This translates into an additional $14.59 and $5.32 per line per month for these lower-density zones.

IV. Summary

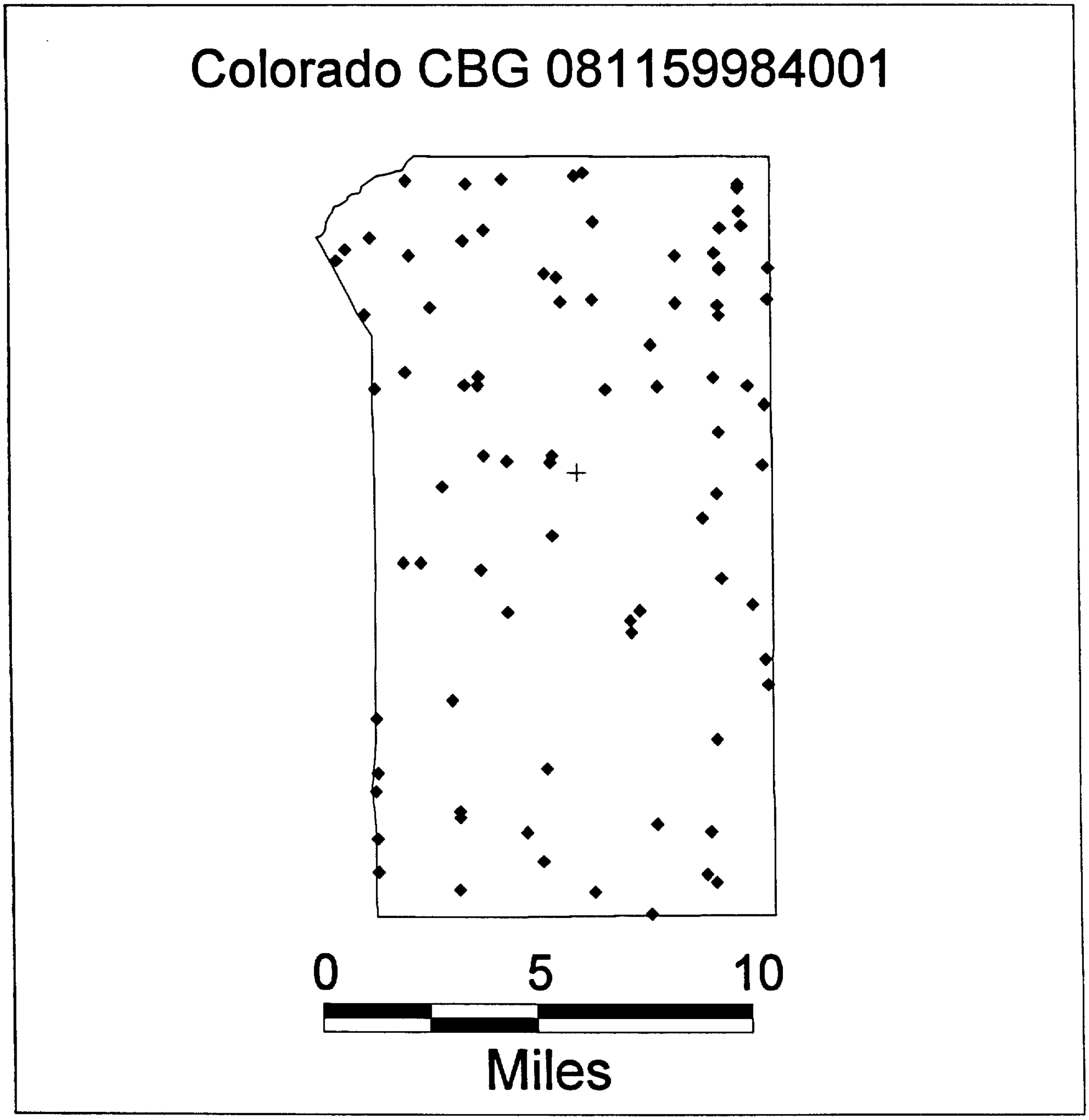
The analysis of the Hatfield 4.0 Model's clustering algorithm suggests that the model assumes too much clustering of customers in the lower-density areas. The mostly arbitrary clustering algorithm attempts to use US Census data on non-farm rural population as an indicator of customer clustering. However, there is very little correlation between the Hatfield Town Factor and actual customer dispersion in the lower-density areas. This can be seen from satellite maps of rural CBG's. This can also be seen from statistical analysis of the Town Factor and a measure of actual dispersion based on customer locations in Census Block groups.

The implication of the Hatfield Model's inability to accurately capture actual customer locations in the rural areas and its arbitrary clustering algorithm is that the Model does not "build" enough plant in the rural areas. A comparison of reported route miles for small telephone companies in Colorado against the route miles "built" by the Hatfield Model for these same companies indicates that the Model under-builds plant, on average, by 40%. The implication for loop cost is that the Model underestimates the facilities and costs necessary to build and operate a wire-based telecommunications network in the lower-density areas. This negative bias was demonstrated by running the Hatfield Model for US West's Colorado service territory and increasing the Town Lot Size to proxy for greater dispersion in the rural areas.

Cost proxy models, because they purport to rebuild existing networks, should accurately account for the current locations of the customers they seek to be serve. Clearly, the Hatfield 4.0 Model fails to meet this challenge.

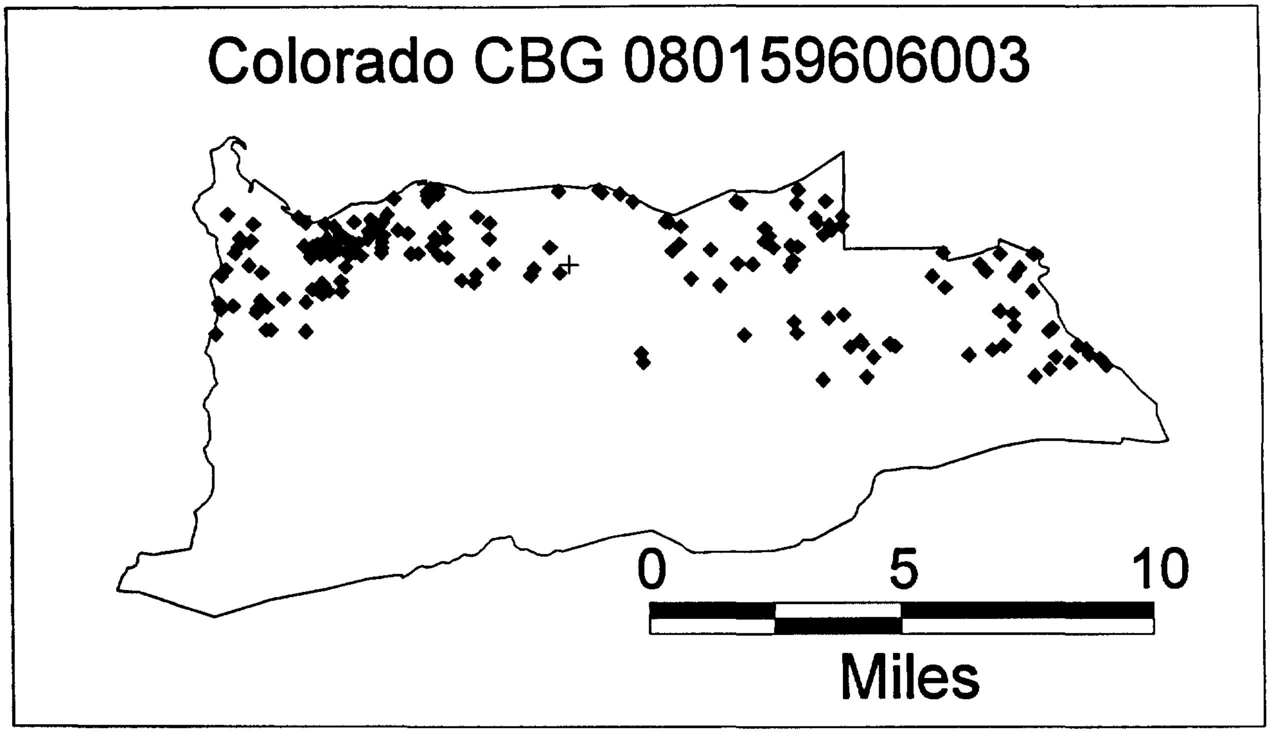
Three Colorado CBG's Less Than 5 HH/SqMi

Satellite Observations

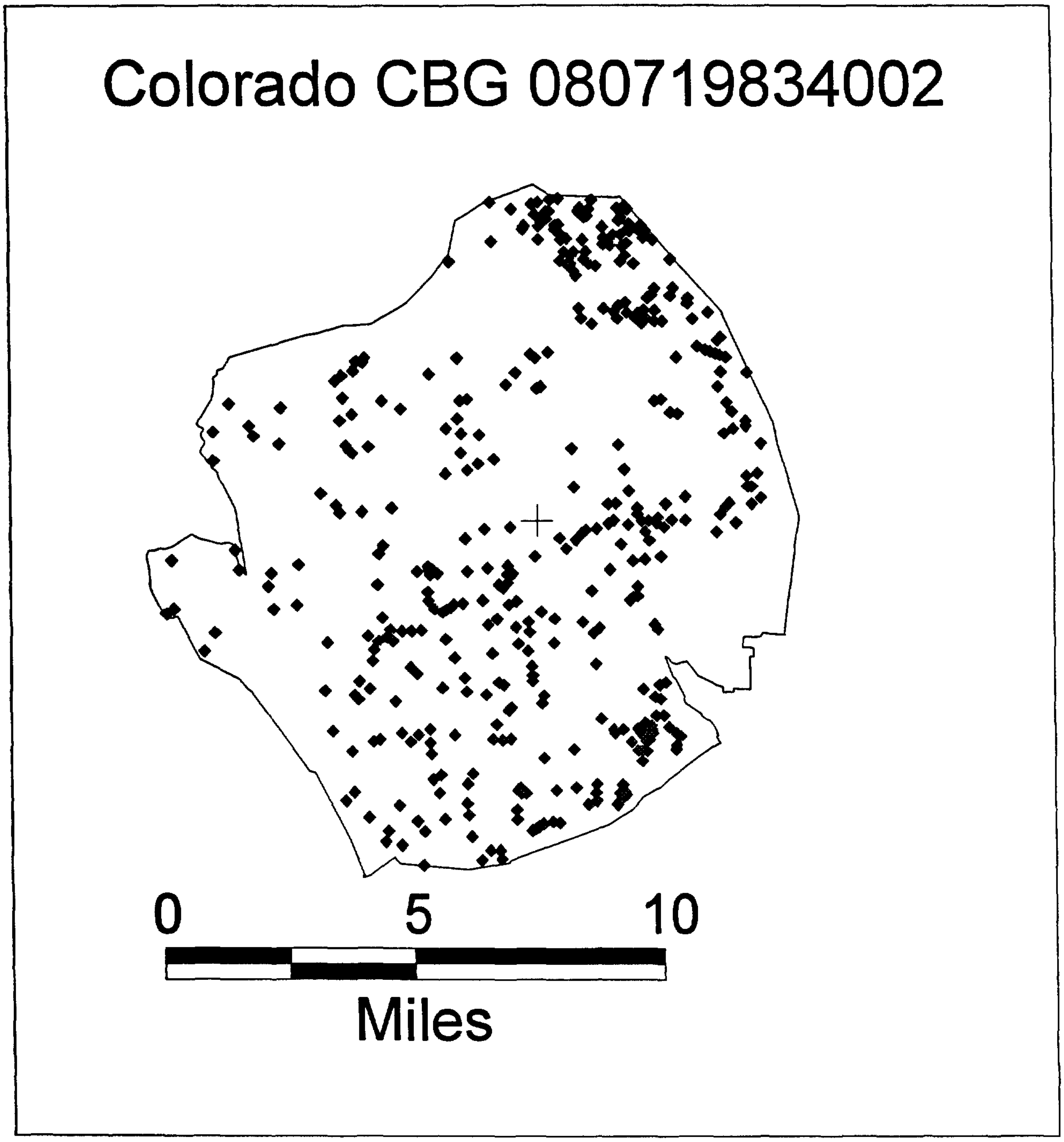


83 Observations

I/legal/skw/wpdata/bcpmcom.doc



181 Observations



411 Observations

1/legal/skw/wpdata/bcpmcom.doc

ATTACHMENT C

BCPM DATA SPECIFICATIONS: GIS DATA

Grid Dimensions

- Grid Dimensions have been set.
  - The largest grid will be 1/25 of a degree Latitude and Longitude in size or approximately 12,000 to 14,000 feet per side
    - This was done to comport with engineering constraints that the maximum copper distribution run can be no longer than 12,000 feet. If, due to placement of the DLC site or re-aggregation[25] of partial grids, the length of a distribution run exceeds 12,000 feet, cable gauge adjustments may be made.
  - The smallest grid will be 1/200 of a degree Latitude and Longitude or approximately 1,500 to 1,700 feet per side.
  - Quadrants will be created within each Grid about the Road Centroid point.
    - The quadrants will be made up of the 1/200 grids whose road centroids fall within it.
    - Road Segments, Households, Housings Units, Multiple Housing Unit data, and Business data will be required for each quadrant.
    - In addition, Road Centroids and Road Reduced areas in each quadrant are required.

Census Block to Grid Apportionment

- The goal of this process is to allocate the Census data for each Census Block into grids. This is accomplished by partitioning each Census Block into all of the 1/200 Grid cells that it spans.
  - For Census Blocks less than 1/4 square mile, the apportionment will be done on land area.
    - For example, if the Census Block falls over 2 grids equally, the Census Block data will be split 50/50 between the two grids.
  - For Census Blocks larger than 1/4 square mile, the apportionment will be based on relative road segment length.
    - For example, if the Census Block spans 10 grids and one of the grids contains 80% of the road length, the grid will be assigned 80% of the Census Block data.
- Any Census Block that falls into un-served LEC territory will be excluded from the BCPM data. However, this data will be output into an exception report for viewing.
- Any Census Block without Households or Business lines will have all of its data excluded before processing.
  - This implies that Road Information will be discarded.

[25] Re-aggregation is defined as the combination of smaller grids to form larger grids.

Grid Aggregation Routines

- Once the Census Block data has been partitioned into 1/200 grids, the Grids will be either output as a single Engineering area or re-aggregated.
- Grid Aggregation algorithms have been modified to comply more closely with CSA-DA engineering guidelines
- **Grid Aggregation general rules**

  Note:

  For the rules, please refer to the following terminology

Grid	=	*1/25 degree Latitude/Longitude Grid*
1/4Grid	=	*1/50 degree Latitude/Longitude Grid*
1/16Grid	=	*1/100 degree Latitude/Longitude Grid*
1/64Grid	=	*1/200 degree Latitude/Longitude Grid*

  If any grid has <1000 HU then output;

  Of remaining data,
  If any 1/64 grid > 400 HU then do:
  - If Grid - 1/64 grid < 400 HU then Output Grid;
  - Else If 1/4Grid - 1/64 grid < 400 HU then Output 1/4Grid;
  - Else If 1/16 Grid - 1/64 grid < 400 HU then Output 1/16Grid;
  - Else Output 1/64Grids (all 4);

  Of remaining data
  If any 1/16 grid > 400 HU then do:
  - If Grid - 1/16 grid < 400 HU then Output Grid;
  - Else If 1/4Grid - 1/16 grid < 400 HU then Output 1/4Grid;
  - Else Output 1/16Grids (remaining 4);

  Of remaining data
  If any 1/4 grid > 400 HU then do:
  - If Grid - 1/4 grid < 400 HU then Output Grid;
  - Else Output 1/4Grids (Remaining 4);

  Clean up
  If any record has < 100 then Merge with horizontal or vertical similar Grid of equal or larger size to which the road centroid leans.
  Partial grids less than 1/5 of a large grid will be aggregated back in (as long as line count is less than 100) to the grid along the longest edge.

Quadrant Data

- Once the Grids have been formed, Quadrants are formed in each grid (except the 1/200 resulting grid).
  - The quadrants are formed at the cross-hair of the Grid's Road Centroid.
    - This implies that the quadrants are not equally sized.
  - The data from the 1/200 grids (before re-aggregation) should be retained to develop the data within each quadrant.
    - This includes: Housing Units, Households, Business Lines, Road Length, and Road Centroid.

- Although there are 4 quadrants, data may not exist for all 4 (some 1/200 grid data will have no data apportioned to it). Therefore, plant may not be built to all 4 quadrants.

___*Data Requirements*

___*(All files are currently in design stage. What follows is the current layouts)*

- Base Grid File: Contains basic data for Grid

___Currently the file layout is defined as follows:

- Clli
- Grid ID (LAT_LONG
- Latitude at Road Centroid
- Longitude at Road Centroid
- FDI Code (Feeder routing code)
- Centroid Distance Feet
- Main Feeder Length
- Sub-feeder Length
- Part 2 Sub-feeder Length
- Total GRID Households
- Total Grid Housing Units
- Number of Housing Units in Single-Unit Detached Structures
- Number of Housing Units in Single-Unit Attached
- Number of Housing Units in Two-Unit Structures
- Number of Housing Units in 3- to 4-Unit Structures
- Number of Housing Units in 5- to 9-Unit Structures
- Number of Housing Units in 10- to 19-Unit Structures
- Number of Housing Units in 20- to 49-Unit Structures
- Number of Housing Units in 50-or-Greater-Unit Structures
- Number of Housing Units that are Mobile Homes
- Number of Housing Units that are None of the Above
- Total GRID Business Lines
- Total GRID Business Locations
- Area-sq Miles
- Depth to Bedrock (Inches)
- Rock Hardness
- Surface Soil Texture
- Water Table Depth (Feet)
- Minimum Soil Slope
- Maximum Soil Slope
- Upper Left Quadrant (ULQ) Number of Housing Units
- ULQ Number of Households
- ULQ Number of Business Lines
- ULQ Road Length
- ULQ Road Reduced Area
- ULQ Road Centroid Latitude
- ULQ Road Centroid Longitude

- Upper Right Quadrant (URQ) Number of Housing Units
- URQ Number of Households
- URQ Number of Business Lines
- URQ Road Length
- URQ Road Reduced Area
- URQ Road Centroid Latitude
- URQ Road Centroid Longitude
- Lower Left Quadrant (LLQ) Number of Housing Units
- LLQ Number of Households
- LLQ Number of Business Lines
- LLQ Road Length
- LLQ Road Reduced Area
- LLQ Road Centroid Latitude
- LLQ Road Centroid Longitude
- Lower Right Quadrant(LRQ) Number of Housing Units
- LRQ Number of Households
- LRQ Number of Business Lines
- LRQ Road Length
- LRQ Road Reduced Area
- LRQ Road Centroid Latitude
- LRQ Road Centroid Longitude

CERTIFICATE OF SERVICE

I, Melinda L. Mills, hereby certify that I have on this 2nd day of September, 1997, served via U.S. First Class Mail, postage prepaid, or Hand Delivery, a copy of the foregoing "Joint Comments of BellSouth Corporation, BellSouth Telecommunications, Inc., US West, Inc., and Sprint Local Telephone Companies to Further Notice of Proposed Rulemaking Sections III.C.1" in the Matter of Federal State Joint Board on Universal Service, CC Docket No. 96-45 and Forward Looking Mechanism for High Cost Support for Non-Rural LECs, CC Docket No. 97-160, filed this date with the Acting Secretary, Federal Communications Commission, to the persons on the attached service list.

Melinda Mills

Melinda L. Mills

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